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April 1995

Agricultural Research Service Progress Report

The Russian Wheat Aphid Seventh Annual Report

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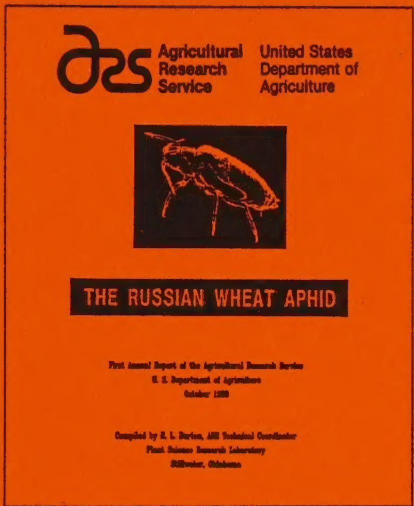

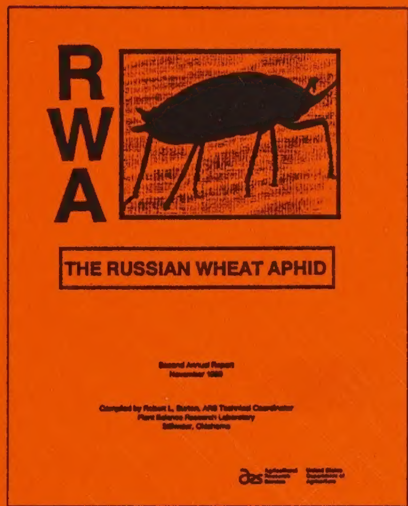

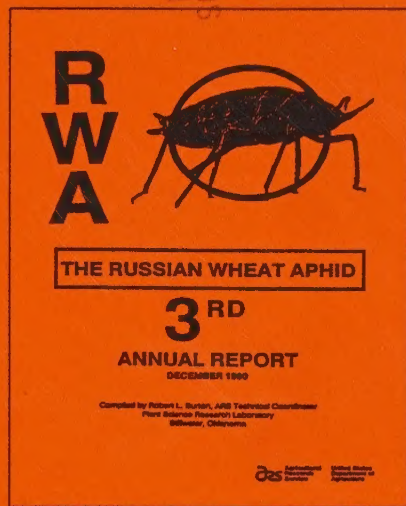

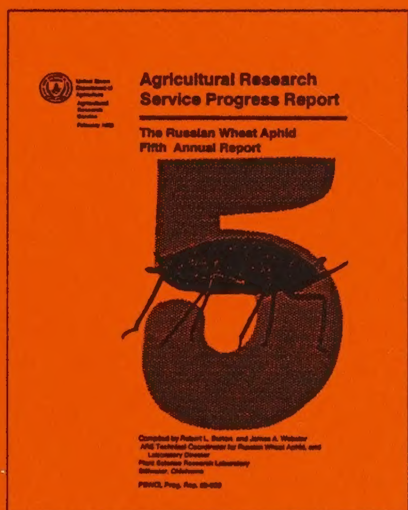

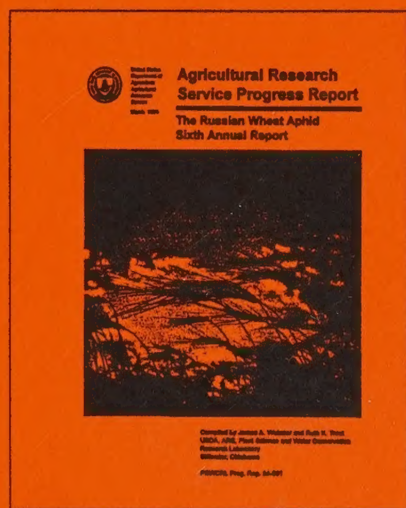

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PSWCRL Prog. Rep. 95-001

Contents

Acknowledgment

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Figures 2 and 3 were provided by Dr. David R. Porter, ARS, PSWCRL, Stillwater, OK.

Material reported herein has been previously cleared for release by individual contributors. For additional information on a particular research effort, contact the contributing scientist(s).

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Introduction

Most of the important U.S. small grain pests were accidentally introduced into this country. These pests include the Hessian fly (1779 in New York), the greenbug (1882 in Virginia), and the cereal leaf beetle (1962 in Michigan). The Russian wheat aphid (RWA) is the newest introduced U.S. small grain pest. It was first detected in the Bailey County, Texas, in 1986, and has spread rapidly to the major wheat and barley producing areas of the western United States. Most of the serious infestations and economic losses have occurred in 17 states west of the 100th meridian (Fig. 1).

The Russian Wheat Aphid Task Force of the Crops and Soils Committee, Great Plains Agricultural Council, has conducted annual economic impact studies of this pest since 1987. Total annual losses have ranged from $12 million in 1991 to over $274 million in 1988. The latest economic data by Webster and Amosson[1] show that estimated yield losses attributed to the RWA in the western United States during the 1992-93 crop year were 4,670,000 bushels, with an estimated value of $17,123,000. This is lower than the previous year and will probably be lower than the 1993-94 crop year, according to unofficial estimates. During the 1992-93 crop year, 325,000 acres were treated with insecticides for the RWA at a cost of $2,395,000. Estimates of cumulative losses for 1987-93 are $432.6 million in direct loss (control costs, yield loss, and grazing loss) and $460.5 million in indirect loss (ripple effects sustained by the regional economy)--a total loss of over $893 million. Additional information about the economic impact of the RWA in the western United States is presented in Figures 2 and 3. Other losses are difficult to calculate and are not included in these estimates. For example, feed barley production has virtually come to a halt in western Nebraska and eastern Wyoming because RWA pesticide treatments are not economically feasible for this crop. In addition, there is some speculation that widespread pesticide applications for RWA control have contributed to the recent development of new greenbug biotypes that are resistant to certain insecticides. The value of these types of losses is unknown, but it is undoubtedly substantial.

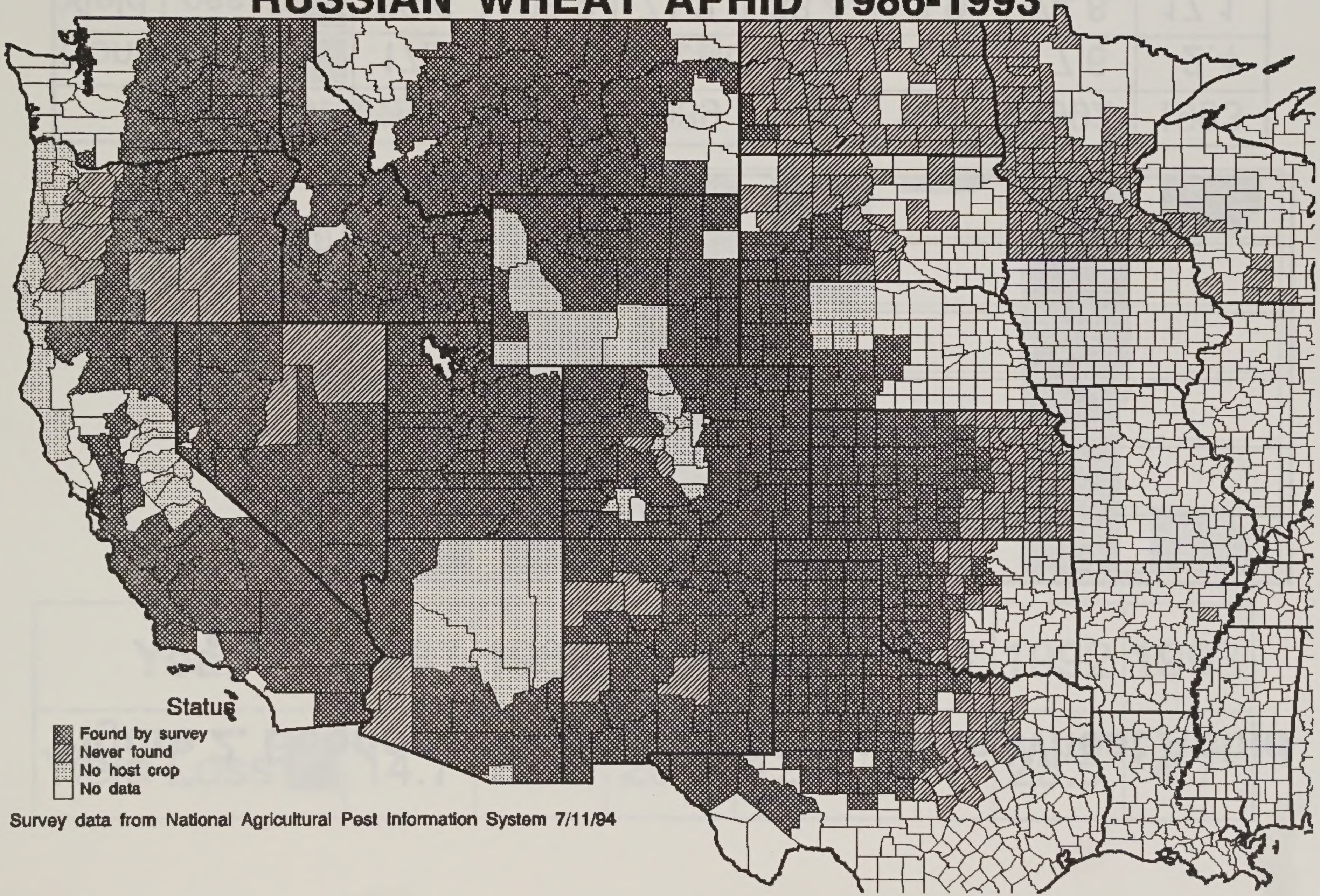
This is the seventh annual report of research progress on the RWA by the Agricultural Research Service of the USDA. As the report indicates, our research is focused on natural control strategies including biological control and the development of RWA-resistant wheat and barley germplasm lines. Several projects fall within these areas and some overlap. For example, we are increasing our knowledge base in areas such as

[1]Webster, J.A. and S. Amosson. 1994. Economic impact of the Russian wheat aphid in the United States: 1992-93. Great Plains Agric. Counc. Publ. 152.

landscape ecology as it relates to aphid populations. We are also learning more about alternate hosts for the RWA as well as alternate aphid hosts for RWA parasitoids. In addition, worldwide biotypic and genetic studies on the RWA and its parasitoids are in progress. Our overall goal is to develop improved pest management systems for the RWA.

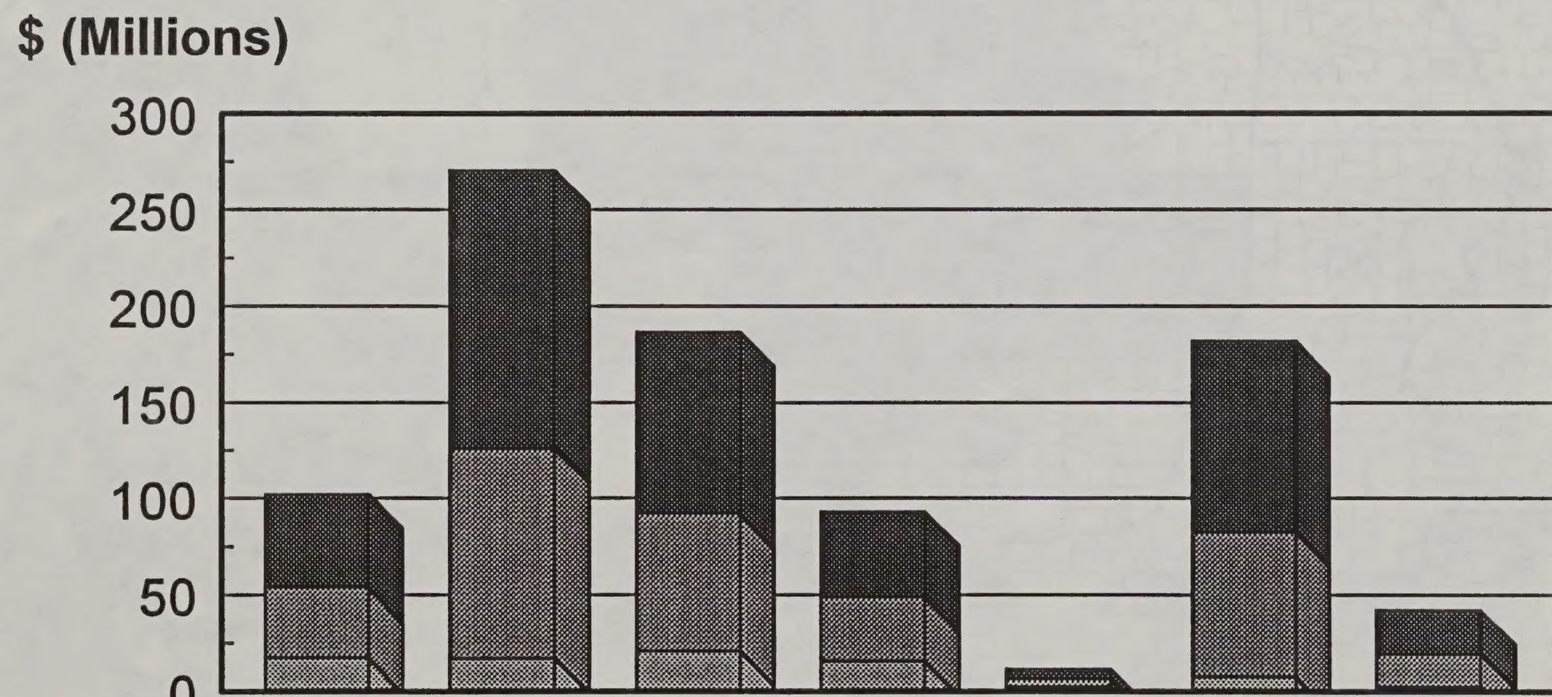
This report is intended as a brief update on the advances in ARS RWA research that have taken place during the past year. Many of our projects are cooperative with organizations including other ARS scientists and locations, as well as scientists from state agricultural experiment stations and USDA-APHIS. These combined efforts provide an excellent model of a cooperative research endeavor and greatly increase the probability of successfully managing the RWA on a regional basis. Space limitations for this report dictate brevity. Additional information about the RWA or specific projects may be obtained directly from the scientists listed in the individual research reports.

RUSSIAN WHEAT APHID 1986-1993



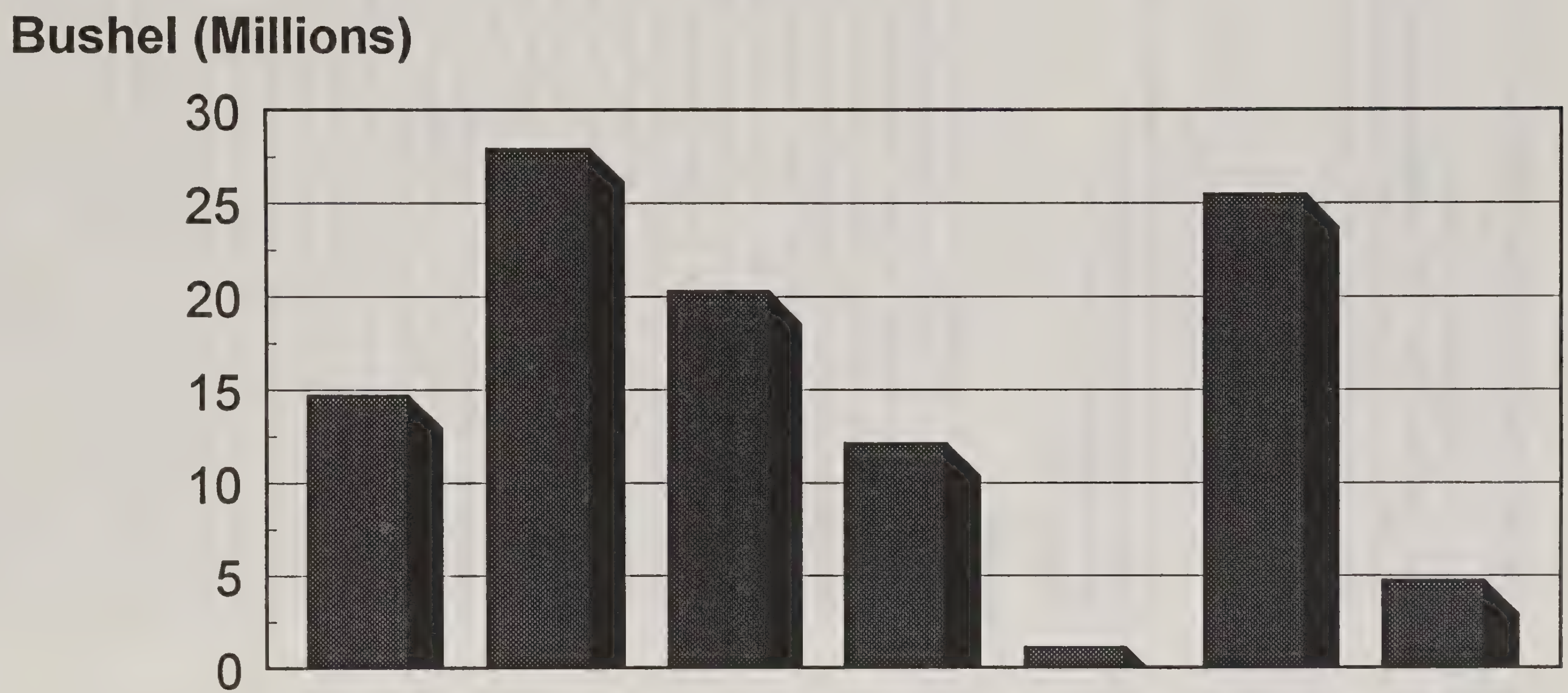
Survey data from National Agricultural Pest Information System 7/11/94

Figure 2. Economic Impact of the Russian Wheat Aphid



Year	1987	1988	1989	1990	1991	1992	1993
Control Cost	17.2	17.0	20.9	15.4	2.5	7.6	2.4
Yield Loss	36.6	108.9	71.2	33.4	3.9	74.8	17.1
Indirect Loss	48.7	144.8	94.7	44.5	5.3	99.7	22.8

Figure 3. Impact of Russian Wheat Aphid on Small Grain Production



Year	1987	1988	1989	1990	1991	1992	1993
Yield Loss	14.7	27.9	20.3	12.1	1.1	25.5	4.7

Stillwater, Oklahoma

Alternate Hosts for Russian Wheat Aphid

Mission: The mission of the Alternate Hosts program is to identify and characterize RWA-resistant germplasm lines that may serve as breeding resources for both cool- and warm-season cereals and turf, range, and conservation grass species.

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Report:
RWA resistance identified in several tall wheatgrass, *Agropyron elongatum* (Host) P. Beauv., plant introduction (PIs) may provide genetic variation necessary to breed RWA-resistant wheat cultivars and improve forage grasses. The Russian wheat aphid, *Diuraphis noxia* (Mordvilko), is a recently introduced insect pest that is a serious threat to wheat, *Triticum aestivum* L., and barley, *Hordeum vulgare* L., production. Tall wheatgrass, not unlike other wheatgrass species, serves as an important alternative summer host of the aphid and provides a bridge for RWA populations between spring harvest and fall planting of cereal crops such as wheat and barley. Experiments were carried out in the greenhouse to identify RWA-resistant PIs obtained from the Western Regional Plant Introduction Station, USDA-ARS, Pullman, WA. One PI (PI 401010) was identified to resist plant damage, leaf curling, and aphid reproduction. Additional experiments were carried out in the greenhouse to characterize the plant components (i.e., antibiosis, antixenosis [nonpreference], and tolerance) contributing to resistance of PI 401010 originally collected in Turkey. PI 401010 was compared with PI 401118, a RWA-susceptible PI, and tall wheatgrass cv. 'Alkar' and 'Jose'. PI 401010 showed high levels of antibiosis, demonstrated by delay in reproductive maturity of the RWA, shorter reproductive lifespan, and reduced rates of nymph production compared with the other genotypes. PI 401010 demonstrated tolerance when compared with the other genotypes when infested with RWAs, although plant height was reduced by aphid feeding, and dry mass foliage loss per unit of aphid mass produced was relatively high. A strong antixenosis resistance component existed in PI 401010 when aphids were given a free choice of several genotypes. PI 401010 is a valuable new source of resistance for germplasm enhancement efforts.

Publications Since Last Report:

Kindler, S.D., T.L. Springer, and K.B. Jensen. Detection and characterization of the mechanisms of resistance to the Russian wheat aphid in tall wheatgrass, *Agropyron elongatum* (Host) P. Beauv. J. Econ. Entomol. (Submitted)

Reed, D.K., and S.D. Kindler. 1994. Report on trip to Argentina and Chile, pp. 163-168. *In* F.B. Peairs, M.K. Kroening, and C.L. Simmons (comps.) Proc. Sixth Russian Wheat Aphid Workshop, Colo. State Univ.

Presentations:

Kindler, S.D. 1994. Report on trip to Argentina and Chile. Proc. Sixth Russian Wheat Aphid Workshop, 23-25 Jan 1994, Fort Collins, CO.

Stillwater, Oklahoma

Host Plant Resistance and Small Grain Germplasm Enhancement

Missions: The mission of the Host Plant Resistance program is to identify resistance sources, study the nature of this resistance, and cooperate with the Small Grain Germplasm Enhancement program in the development and release of RWA-resistant small grain germplasms. The mission of the Small Grain Germplasm Enhancement program is to identify, characterize, and introgress genes conferring RWA resistance for small grain germplasm enhancement.

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Report:

Wheat - Approximately 7,500 wheat accessions were evaluated for RWA resistance; 76 of these were identified as having some level of resistance and have been targeted for further testing. Germplasm enhancement for RWA continued. Selected resistant lines have been backcrossed and/or topcrossed to cultivars for the development of elite RWA-resistant germplasm. Several germplasm releases with different resistance genes are forthcoming. Studies on a RWA-resistant selection from PI 225217 indicated that tolerance is the most important mechanism of resistance and it is inherited as a single, dominant gene. Genetic analysis of three additional lines has been completed. In all cases, inheritance of resistance was controlled by two genes. Genetic analysis of additional lines is continuing. In order to identify and enhance genetic diversity, allelism tests of identified sources of resistance are ongoing. Transfer of RWA resistance genes from triticale to wheat continued. Several populations resulting from x-ray irradiation therapy were advanced. RWA-resistant wheat plants were recovered which will be cytologically examined to determine chromosomal complement. RWA resistance evaluation of various wheat accessions from around the world continued.

Barley - Although the bulk of the ARS National Barley Collection has been evaluated for RWA resistance, evaluation of new, untested accessions continued. Genetic testing of F_1, RF_1, BC, F_2, and F_2-derived F_3 families of five RWA-resistant germplasm lines was completed. Data analysis is ongoing to determine the number of genes and gene action controlling resistance in these lines. A total of 349 crosses were made: 187 backcrosses made for cultivar development and/or for future genetic studies, 99 F_1's and RF_1's between resistant lines and susceptible cultivars made for cultivar development and future genetic analysis, 47 F_1's between resistant lines made for future tests for genetic diversity, and 16 backcrosses made between the F_1 of two resistant lines and a susceptible cultivar for genetic diversity studies. Data collection and analysis from a field experiment in Wyoming to determine the effect of RWA infestation on yield, yield components, and malting quality of germplasm lines differing in greenhouse seedling resistance ratings. Screening of a total of 271 advanced generation populations, 24 BC populations, 11 wide hybrid populations, and 100 doubled haploids was done for seven barley breeders. Selected plants were sent to the breeders for crossing and/or grown in Stillwater for seed increase. Three hundred F_2-derived F_3 families were increased for each of 16 populations for future genetic analysis. Forty-four F_2 populations were also increased.

Field experiments were conducted to characterize field RWA resistance of barley germplasm and examine their impact on RWA field populations and parasite activity. RWA-resistant lines varying in seedling resistance rating and four susceptible checks were grown in plots in the field in Wyoming. The center rows of some plots were infested with RWA at early tillering. Noninfested controls were kept RWA free by repeated applications of insecticide. RWAs were present on the resistant lines and were more abundant on the moderately resistant lines. There were few differences in parasitism among the barley lines. In general, the moderately resistant lines harbored as many aphids and had parasitic activity at levels near those of the susceptible lines. RWA feeding had no significant effect on grain yield and yield components on barley rated as resistant (greenhouse seedling rating of 2-4 on a scale of 1 to 9). Lines rated as susceptible sustained significant losses from RWA feeding. Field resistance of lines rated moderately resistant as seedlings was not accurately predicted. These resistant lines do not appear to have detrimental effects on RWA parasitic activity. Therefore, these lines would fit well into an integrated pest management system.

Experiments designed to identify biochemical and physiological mechanisms associated with RWA resistance in barley continued. The effects of RWA feeding on resistant and susceptible barley were visualized through silver-staining of denatured leaf proteins separated by two-dimensional polyacrylamide gel electrophoresis. Comparisons among protein

profiles of RWA-infested and noninfested leaf tissue showed that differential cellular responses could be detected in resistant and susceptible plants. Specifically, a protein complex in the range of approximately 24 kilodaltons is dramatically inhibited in the susceptible genotype, while synthesis and accumulation continues in the resistant genotype. Comparison of the electrophoretic mobility of this protein complex with known proteins suggests that this complex may be the light harvesting complex protein of photosystem II (LHCPII). We have obtained the antibody to LHCPII and will be doing Western blot analysis to confirm the identity of the differentially affected protein complex. Identification of this protein complex will aid in the development of RWA-resistance enhancement strategies.

Publications Since Last Report:

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Brewer, M., D. Mornhinweg, and J. Struttmann. 1994. Biocontrol agents and aphids companion to Russian wheat aphid occuring on barley resistant to Russian wheat aphid, pp. 107-116. *In* F.B. Peairs, M.K. Kroening, and C.L. Simmons (comps.) Proc. Sixth Russian Wheat Aphid Workshop, Colo. State Univ.

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Mornhinweg, D.W., M. Brewer, and J. Struttmann. 1994. Effect of RWA on yield and yield components of barley lines differing in seedling damage response: A field assessment, pp. 117-120. *In* F.B. Peairs, M.K. Kroening, and C.L. Simmons (comps.) Proc. Sixth Russian Wheat Aphid Workshop, Colo. State Univ.

Mornhinweg, D.W., M.J. Brewer, J. Struttmann, and D.R. Porter. 1994. Field evaluation of RWA-resistant barley germplasm lines under RWA infestation. Agron. Abstr., Am. Soc. Agron. p. 110 .

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Porter, D.R., H.T. Nguyen, and J.J. Burke. 1994. Quantifying acquired thermal tolerance in winter wheat. Crop. Sci. 34: 1686-1689.

Stillwater, Oklahoma

RWA-Host Plant Interaction and Insect Genetics

Missions: The mission of the RWA-Host Plant Interaction program at Stillwater is to characterize plant physiological and biochemical responses to RWA attack in resistant and susceptible germplasm to identify superior metabolic systems, pathways, or individual components critical to genetic resistance. The mission of the Insect Genetics program is to conduct national and worldwide biotypic and genetic studies on the RWA and its parasitoids.

Personnel:

RWA-Host Plant Interaction

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Report:
Nuclear genetic markers are being utilized to study RWA populations and the *Diuraphis* spp. complex in the United States. A genomic library of RWA has been produced from which the rRNA genes are being cloned. From this library, six positive recombinants have been identified after low stringency hybridizations with the greenbug rDNA probe pGBE. The inserts will be subcloned into pUC19 for restriction mapping. After a sufficient portion of the rRNA cistron of RWA has been cloned and mapped, it will then be used in a genetic analysis of RWA populations. Of most interest is the intergenic spacer (IGS) which has been a useful fingerprinting probe in the greenbug. The IGS will be used to measure genetic diversity of RWA found on non-cultivated hosts and to ascertain their importance in maintaining total population diversity. Collections of RWA from cultivated and non-cultivated hosts in Kansas, Nebraska, Wyoming, and Colorado were made at 2-month intervals and will serve as the basis for this study as well as establishing the importance of non-cultivated hosts as bridges for population movement to wheat and barley. These collections will also be compared with previous collections made during 1986-1990 in an attempt to determine if or how the genetic diversity of RWA populations in the United States has changed. A biotype survey of RWA found in the United States will be based on these collections as well.

Random amplified polymorphic DNA (RAPD) is being developed to aid in the identification of four *Diuraphis* spp. found in the United States (*D. noxia*, *D. tritici*, *D. nodulus*, and *D. frequens*). Thus far, almost all 10-mer oligonucleotide primers tested have

yielded species-specific banding patterns. To further test RAPD's applicability to identification of *Diuraphis* spp., additional populations of each species will need to be tested, as well as testing for homology among shared bands. Phylogenetic relationships of North American *Diuraphis* spp. will be inferred from mtDNA sequence analysis.

Stillwater, Oklahoma

Biological Control

Mission: The mission of the Biocontrol program at Stillwater is to develop strategies in the laboratory, greenhouse, and field for maximum utilization of natural enemies (exotic, naturalized, and endemic) in RWA-infested cereals and grasses.

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Report:

Release and Recovery of Imported Parasitoids in Eastern Colorado - The exotic hymenopterous parasitoids *Aphelinus asychis* Walker, *Aphelinus albipodus* Hayat and Fatima, *Aphelinus varipes* (Forester), *Diaeretiella rapae* M' Intosh, *Aphidius colemani* Viereck, *Aphidius matricariae* Haliday, and *Ephedrus plagiator* (Nees) were released at several sites in eastern Colorado from 1991 through 1994 in an attempt to establish the species in wheat agroecosystems for biological control of the Russian wheat aphid (RWA). The majority of parasitoids were released at sites in Baca and Prowers Counties. Over the 4 years of releases, parasitoid numbers in cages increased approximately eight times on average during the 2-3 weeks they were caged compared with numbers initially placed in cages. Approximately 1.6 million exotic parasitoids were released during the 3 years. Three species, *A. asychis*, *D. rapae*, and *A. albipodus,* accounted for the majority of parasitoids released in terms of total numbers and number of release sites, while only small numbers of *A. matricariae* and *E. plagiator* were released, each on a single occasion. Recovery of *A. asychis* and *A. albipodus* near Akron, CO, in 1994, and *A. asychis* near Pritchett, CO, in 1994, one year after releases were made at the locations, indicates that exotic species had established populations. Recovery of *D. rapae*, an endemic species, in relatively high numbers in 1994 near Akron, where previous surveys had shown rare incidence of parasitism of RWA by this species, suggests that an exotic strain of *D. rapae* may also have established. However, the increase in parasitism of RWA by *D. rapae* may reflect annual variation in parasitism rates by native *D. rapae* or adaptation by native *D. rapae* to the recently introduced host.

Effects of *Coccinella septempunctata* on Aphidophagous Coccinellid Communities in Crops - Exotic coccinellids, such as *Coccinella septempunctata*, have been introduced in the United States for biological control of the RWA and other aphid pests. Because of its broad habitat range and voracity, there has been concern that *C. septempunctata* may competitively displace some native aphidophagous coccinellids. Long-term studies conducted at the same location are often essential to reliably delineate pattern or trend in ecological processes that exhibit high temporal variability. Long-term monitoring of native coccinellid populations prior to and after establishment may provide the information needed to determine if invasion by *C. septempunctata* has had an adverse effect on native coccinellid populations. This study was conducted to determine whether the structure of coccinellid communities in agricultural crops (alfalfa, corn, and small grains) in eastern South Dakota was altered by invasion and establishment of *C. septempunctata* in the region in 1987. Coccinellid assemblages in these crops were intensively monitored for 13 years prior to, and 5 years after, the establishment of *C. septempunctata* in the region. Resulting data were used to compare coccinellid species abundances and community structure prior to and after establishment of *C. septempunctata*. Seven species of native coccinellid commonly occurred in alfalfa, corn, and small grain fields in eastern South Dakota prior to invasion and establishment by *C. septempunctata* L. The structure of native coccinellid communities differed significantly for years prior to establishment of *C. septempunctata* in the three crops compared with years after establishment. Differences in community structure were accounted for mainly by reduced abundance of two species, *Coccinella transversoguttata richardsoni* Brown and *Adalia bipunctata* (L.). Annual abundance of *C. transversoguttata. richardsoni* was 20-32 times lower during post-invasion years than in years prior to invasion, depending on crop. Annual abundance of *A. bipunctata* averaged 20 times lower in corn after invasion than before invasion. Addition of *C. septempunctata* to the community did not significantly increase in total coccinellid abundance in the crops. Coccinellid abundance in agricultural crops may be limited by the total abundance of prey or by the availability of other requisites in the landscape as a whole. Therefore, introduction of new species, while resulting in reductions in native species populations, may not increase total coccinellid abundance, and may therefore have little or no net effect on biological control of aphid pests of field crops.

Publications Since Last Report:

Elliott, N.C., J.D. Burd, J.S. Armstrong, C.B. Walker, D.K. Reed, and F B. Peairs. Release and recovery of imported parasitoids of the Russian wheat aphid in eastern Colorado. Southwest. Entomol. (In press)

Elliott, N.C., B.W. French, J.D. Burd, S.D. Kindler, and D.K. Reed. 1994. Parasitism, adult emergence, sex ratio, and size of *Aphidius colemani* on several aphid species. Great Lakes Entomol. 27:137-142.

Elliott, N.C., B.W. French, G.J. Michels, Jr., and D.K. Reed. 1994. Influence of four aphid prey species on development, survival, and adult size of *Cycloneda anchoralis*. Southwest. Entomol. 19:57-61.

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Elliott, N.C., R.W. Kieckhefer, and W.C. Kauffman. Effects of an invading coccinellid on native coccinellids in an agricultural landscape. Oecologia. (Submitted)

Elliott, N.C., D.K. Reed, B.W. French, and S.D. Kindler. 1994. Aphid host effects on the biology of *Diaeretiella rapae*. Southwest. Entomol. 19:279-284.

Reed, H.C., S.H. Tan, K. Haapanen, M. Killmon, D.K. Reed, and N.C. Elliott. Olfactory responses of the parasitoid *Diaeretiella rapae* (Hymenoptera: Aphidiidae) to the odor of plants, aphids, and aphid-plant complexes. J. Chem. Ecol. (In press)

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Brookings, S. Dakota

RWA-Host Plant Interaction

Mission: The mission of the RWA-Host Plant Interaction program at Brookings is to develop and evaluate sustainable production systems that enhance environmental quality and provide health, safety, and profitability for agriculture in the Northern Great Plains, with emphasis on crop and pest management.

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Report:

Evaluation of the Aphid-Day Standard as a Predictor of Yield Loss Caused by Cereal Aphids - Accurate prediction of yield loss caused by cereal aphids in small grains involves assessment of the aphid population density on plants, the duration of their feeding, and the growth stage of the crop at the time of feeding. In this research, aphid-day (one aphid feeding on a plant for 24 hours) unitage was used as a standard to compare the effects of feeding by the greenbug (GB), *Schizaphis graminum* (Rondani); Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko); and the bird cherry-oat aphid (BCO), *Rhopalosiphum padi* (L.), on the growth and yield of spring wheat, *Triticum aestivum* L., to measure the degree of additivity of yield loss caused by aphid-feeding on the same plants at several stages of plant growth, and to evaluate the adequacy of the aphid-day standard as a predictor of yield loss. Results of greenhouse experiments with a scaled series of aphid-day components (150 aphids x 2 days; 75 x 4 days; 25 x 12 days) of equal total value (300 aphid-days) showed that the three aphid species were similarly damaging to yield but that the RWA and BCO 25-x-12-day combinations were significantly ($P \leq 0.01$) more damaging than the other aphid-day treatments for those species. The administration of escalating aphid-day dosages to plants concomitant with advancing plant growth stages (2-leaf, 300 aphid-days; 4-leaf, 400 aphid-days; 2-leaf + 4-leaf, 700 aphid-days; boot, 1200 aphid-days, 2-leaf + boot, 1500 aphid-days; milk, 200 aphid-days; 2-leaf + milk, 2300 aphid-days) revealed that yield loss caused by aphid-feeding at two plant growth stages was usually significantly ($P \leq 0.01$) greater than that at a single stage but was not fully additive simply as the arithmetic sum of the yield losses at the two stages. Yield losses due to aphid feeding (expressed as mg per 100 aphid-days) declined precipitously with advancing plant growth stage. These results demonstrated that the aphid-day

unitage, properly interpreted in relation to the aphid species involved and the growth stage of the crop, is a useful prediction of grain yield loss at harvest. Relating cumulative aphid-days at successive plant growth stages to ultimate yield loss enables producers to make informed decisions about the need for and timing of rescue chemical treatments.

Feeding Damage Effects of Three Aphid Species on Wheat Root Growth - Cereal aphid infestations have considerable impact upon productivity and profitability of U.S. agriculture. A comparison study of the influence of different aphid species (RWA, GB, and BCO) upon shoot characteristics and root growth of hard red spring wheat was conducted in an attempt to better understand the mechanisms of yield loss in aphid-damaged plants. Plants infested with aphids showed similar reductions in shoot growth regardless of aphid species. Shoot chlorophyll concentrations were lowest in greenbug-infested plants. Root length and dry weight were also equally reduced by feeding damage by the three aphid species. Upon removal of the aphids, shoot dry weights of plants damaged by each aphid species remained unchanged for 10 days. Shoot dry weights for aphid-damaged plants were about half the magnitude seen n the control plants after 15 days. Chlorophyll concentrations seen in GB- and RWA-infested plants initially were lower than the concentrations seen in BCO-infested and control plants. Within 10 days after aphid removal, however, chlorophyll concentrations across all treatments were essentially equal. Root lengths in plants previously infested with GB or RWA were lower than control plants 4 days after aphid removal. Within 10 days after aphid removal, root lengths in plants previously infested with GB or RWA did not differ from control plants. Root lengths in plants previously damaged by BCO did not reach the same magnitude as that of the other treatments until 27 days after aphid removal. These results indicate that aphid feeding damage to wheat plants can have significant effects on root growth, suggesting that crop management practices that promote root growth could play important roles in improving plant tolerance to aphid damage.

Publications Since Last Report:

Kieckhefer, R.W., J.L. Gellner, and W.E. Riedell. Evaluation of the aphid-day standard as a predictor of yield loss caused by cereal aphids. Agron. J. (In press)

Riedell, W.E., and R.W. Kieckhefer. Feeding damage effects of three aphid species on wheat root growth. (Submitted)

Beltsville, Maryland

Biosystematics

Mission: The mission of the Biosystematics program is to provide identifications and verifications for RWA and its natural enemies.

Personnel:

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Report:

Dr. Stoetzel continued to provide identifications and verifications for *Diuraphis noxia* (Mordvilko). No other activities regarding RWA were reported for 1994.

Ithaca, New York

Biological Control

Mission: The mission of the Biological Control program at Ithaca is to develop fungal pathogens of RWA, devise strategies for the introduction of fungi for RWA control in the field, and provide taxonomic support to other scientists studying RWA pathogens.

Personnel:

John D. Vandenberg, Research Entomologist
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Report:

A variety of laboratory studies of RWA susceptibility to fungal infection were done in 1994. For laboratory bioassays, aphids were reared on susceptible barley in small pots at 25°C and 16:8 LL:DD in a quarantine laboratory with attached rearing rooms. Adults aged 0-2 days were obtained by confining gravid females on plants. After 2 days the parents were removed and the nymphs were incubated for 7-9 days. After this time, the young adult aphids were transferred from potted plants to leaf pieces embedded in 3% water agar and sprayed with suspensions of spores. At day 1 and day 4 after spraying, aphids were transferred to fresh leaf pieces. This method facilitates daily monitoring of aphid survival and infection--necessary for accurate assessment of the dynamics of aphid-pathogen interactions. Survival of control-inoculated aphids using this method is nearly 100%.

In a series of multiple dose assays, aphids were tested for their susceptibility to single-spore isolates of *Beauveria bassiana* (ARSEF 4100, originally isolated from RWA) and *Paecilomyces fumosoroseus* (ARSEF 4461, isolated from the sweet potato whitefly and passaged through RWA). For *B. bassiana,* LC_{50}s ranged from 2.5 to 5.0 colony-forming units (CFUs) per mm^2; slopes ranged from 1.45 to 2.04. For *P. fumosoroseus*, LC_{50}s ranged from 0.4 to 3.4 CFUs/mm^2; slopes ranged from 1.10 to 1.31. Single-dose comparisons were used to screen 25 other isolates of *B. bassiana*. Potency ratios, compared with ARSEF 4100, ranged from 0 to 2.7. Seventeen isolates of *P. fumosoroseus* were also screened using ARSEF 4461 as the standard. Potency ratios ranged from 0 to 4.1. Times to death ranged from 2 to 7 days after inoculation. Based on LC_{50} estimates and the range of potency ratios, either of these fungi has potential as a control agent for RWA.

For two isolates of *P. fumosoroseus*, suspensions of aerial conidia, submerged conidia, and dried submerged conidia were

tested at a single dose against RWA. Aerial conidia of ARSEF 4461 were used as a standard. The experiment was repeated three times for each isolate. Spores produced in submerged culture resulted in the shortest times to death and the most consistent mortality levels. Production of these fungi in submerged culture for insect control is now being tested commercially. This project was conducted in cooperation with M. Jackson (USDA-ARS, Peoria, IL) and L. Lacey (USDA-ARS, Montpellier, France).

Laboratory evaluation of the efficacy of fungi produced by various methods will continue. RWA reared on resistant and susceptible wheat or barley will be tested for differences in susceptibility to fungal infection. Laboratory tests of the susceptibility of certain RWA predators to fungi are planned. Field tests of commericial formulations of both *B. bassiana* and *P. fumosoroseus* as RWA control agents are also planned for 1995.

Publications Since Last Report:

Vandenberg, J.D. 1994. Bioassay of entomopathogenic fungi against the Russian wheat aphid. 6th Int. Colloq. Invertebr. Pathol. Microb. Control, Montpellier, France. p. 126.

Montpellier, France

Biological Control

Mission: The mission of the Biological Control program at the European Biological Control Laboratory in Montpellier is to collect, study, and import natural enemies and entmopathogens of the RWA, and to study their interactions with other natural enemies of RWA.

Personnel:

Keith R. Hopper, Research Entomologist (reassigned to Ithaca)
Lawrence A. Lacey, Insect Pathologist
David J. Kazmer, Research Entomologist
FSN Staff: Kim Chen
Dominique Coutinot
Guy Mercadier
Natalie Ramualde-Serviat
Students: Antonio Mesquita
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Visiting Scientists: Peter Mason, Agriculture Canada
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Report:

Parasitoid Studies - We explored and collected in France and Israel. From these collecions, we reared and shipped 13,883 predators and parasitoids (*Aphelinus asychis*, *Diaeretiella rapae*, *Aphidius* spp., *Ephedrus* spp., *Leucopis* spp., and Coccinellidae) to U.S. quarantine. Pathogens were also collected in Israel.

Field exclosure experiments to measure the impact of natural enemies were conducted in Colorado and in Hungary. Data are now being analyzed.

To measure genetic variation among populations in fitness attributes of *A. asychis*, populations from China, France, Greece, Kazakstan, Morocco, and Spain were crossed. There appears to be pre-zygotic reproductive isolation between the Chinese, Kazaki, and Mediterranean basin populations. Within the Mediterranean basin, all populations appeared to be compatible, although in some cases crosses in one direction appeared to yield fewer than expected female progeny. The data on other characters are now being analyzed.

Phenotypic variation among populations of *A. asychis* in the relationship between temperature and walking speed was

measured by video tracking wasps cooled or heated to various temperatures. Although walking speed varied with temperature, no consistent differences were found between wasp populations from China, Montpellier, and Morocco.

To determine the mating structure of *A. asychis* in the Montpellier area, mummies were collected on sentinel plants placed in the field in May and June. Genic and genotypic frequencies among wasps that emerged from mummies collected on these plants are being analyzed using isozyme loci. These data will be used to determine the spatial scale of mating.

To test the effect of numbers released on mating success of *A. asychis*, releases were made at paired sites in wheat near Fort Collins, CO. Information from these tests suggest small dispersal distances for *A. asychis* in wheat fields heavily infested with *D. noxia*.

In the laboratory, time to mating did not affect the progeny sex ratio produced by *A. asychis* females. Because fecundity did not differ between virgin and mated females, this means that females mating later in life produced progeny with a male-biased ratio.

Diuraphis noxia nymphs and adults exposed to *A. asychis* and *Aphidius matricariae* defended themselves by kicking, bucking, rotating, walking, and exuding liquid via their cornicles. However, none of these behaviors appeared to reduce the probability of being parasitized by either wasp species.

To test the effect of host of origin on parasitization, *Aphelinus varipes* collected from *Rhopalosiphum padi* (bird cherry-oat aphid) and from *D. noxia* were exposed to *R. padi* and *D. noxia*. Results suggested that *A. varipes* from *D. noxia* had adapted partially, but not completely, to *D. noxia*. Direct observations showed that *A. varipes* from *R. padi* and from *D. noxia* stung equal numbers of *R. padi* and that parasitoids from the two host species also stung equal numbers of *D. noxia*. However, parasitoids from both hosts stung *R. padi* more readily than *D. noxia*. Dissections showed that *A. varipes* from the two host species almost always laid an egg when a host was stung and that the frequency of ovipostion did not differ between hosts of origin or hosts of exposure. Thus, it appears that the difference in adaption to *R. padi* versus *D. noxia* results from differences in host suitability. Further tests also indicated that at least some of the adaptation to *D. noxia* is genetic.

In the laboratory, *Leucopis ninae* larvae had to consume at least 40 3rd-4th instar *D. noxia* to pupate and emerge as adults. Adult body size and fecundity depended on the number of aphids consumed. The data comparing prey consisting of three other cereal aphid species suggest that *D. noxia* may not be the most prefered prey of *L. ninae*.

Previous experiments have shown that the syrphids *Episyrphus balteatus* and *Eupeodus corollae* differ in their ovipostion behavior: *E. balteatus* oviposits on plants without aphids or signs of aphid presence, but *E. corollae* does not; *E. balteatus* lays eggs farther from aphid colonies than *E. corollae*; and *E. balteatus* lays more eggs at a given aphid density than *E. corollae*. These differences in behavior led us to test several predicitons. In laboratory experiments, two predictions proved true: *E. balteatus* larvae lived longer without aphids than *E. corollae* larvae, and *E. balteatus* larvae crawled faster than *E. corollae* larvae. One prediction was partially born out: limited aphid supply reduced larval and pupal survival, but not adult body size, more for *E. corollae* than for *E. balteatus*.

Entomopathogen Studies - Over the past 3 years, exploration for pathogens of cereal aphids and other aphids has been conducted in France, Spain, Crete, the Middle East, Western Asia, and Malaysia. Isolates of fungi in the Entomophthorales and Hyphomycetes have been accessioned into the EBCL collection, and most of these have been forwarded to the USDA-ARSEF collection of entomopathogenic fungi in Ithaca, NY. Although exploration for fungi of RWA and other aphids is still being made at EBCL, program emphasis has shifted over the past year to lab- and field-oriented research involving the fungi that have been isolated from RWA and other aphids. A principal theme in this research is the interaction of these fungi with other natural enemies of *Diuraphis noxia*.

Studies were conducted at the EBCL insect pathology lab to determine the pathogenicity of the fungus *Paecilomyces fumosoroseus* for *D. noxia* and its effect on development, longevity, and parasitic activity of the parasitoid *Aphelinus asychis*. The fungus was isolated from the whitefly, *Bemisia tabaci*, in Multan, Pakistan.

Our results indicate that *P. fumosoroseus* demonstrated good insecticidal activity against RWA and warrants further consideration for development as a microbial control agent of this pest. Our studies also indicate that a high degree of compatibility between *P. fumosoroseus* and *A. asychis* is possible. On-going research at EBCL indicates that aphids that are first parasitized by *A. asychis* are protected from fungal infection and aphids that are patently infected by the fungus are usually not selected as hosts by the parasitoid. However, *A. asychis* did oviposite in aphids that were in the initial stages of infection. Additional research to investigate the effects of environmental factors and timing of application of fungus and parasitoid on enhanced interaction against RWA is warranted. Increased knowledge of the interaction of *A. asychis* and fungal pathogens of RWA will better enable their combined use in integrated control programs.

Studies are currently underway on the antimycotic activity induced by parasitization of RWA by *A. asychis*, foraging

behavior of *A. asychis* after treatment with *P. fumosoroseus* under various environmental conditions, and competetive interaction of *P. fumosoroseus* and other entomopathogenic fungi. Field studies to be conducted in the spring of 1995 near Montpellier will evaluate the combined activity of *P. fumosoroseus* and *A. asychis*. Cooperative research with USDA-ARS labs in Ithaca, NY (J. Vandenberg et al.) and Peoria, IL (M. Jackson) concerns the production of infectious propagules of *P. fumosoroseus* in liquid media and their activity against RWA.

Publications Since Last Report:

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